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A KNOWLEDGE-BASED SYSTEM FOR STEREO VIDEO MEASUREMENT

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Abstract:

A knowledge-based system has been developed to perform stereo measurement from video images. The system, called DRSTEREO, is consisted of four modules: image measurement, calibration, relative orientation, and absolute orientation. It is designed to run under DOS, with the knowledge-based component performing the following functions: 1) blunder detection and data snooping, 2) guidance, diagnostics, and counselling in failure modes during data processing, 3) accuracy analysis through error propagation, and 4) warnings on weak geometric solutions. The result is a user friendly system that can be used productively without any in-depth knowledge about photogrammetry.

INTRODUCTION

Video camcorders, frame grabbers, and personal computers form the basic components of a video photogrammetric measurement system. These components are fast becoming common household items. They are widely available in scientific laboratories and engineering offices. At the same time, recent research have shown that accurate geometric measurements can be performed using these systems. The major obstacles to the common adaptation of such systems for stereo photogrammetric measurements are the lack of 1) a practical method of camera calibration that requires no special calibration facility, and 2) a user friendly software package that does not require in-depth knowledge about photogrammetry from the user. A companion paper (Wong and Obaidat, 1993), also to be presented at this conference, will introduce a method of camera calibration that requires only a flat brick wall as calibration control field. This paper will discuss the development of a knowledge-based system, called DRSTEREO, for stereo video measurement.

DRSTEREO

DRSTEREO was designed with the following specific objectives:

1. It is to be run under DOS, and requires only VGA graphic support.
2. It must be user friendly, and requires no in-depth knowledge about photogrammetry.
3. It is capable of measuring image coordinates to sub-pixel.
4. It provides full error estimation and accuracy evaluation in 3D measurement.

The end result is a software package that can be run using 286-class or higher personal computers (PC).

DRSTEREO consists of four modules: 1) image coordinate measurement; 2) camera calibration; 3) relative orientation; and 4) absolute orientation. The coordinate measurement module is used to measure image coordinates in digital images, which can then be used as direct input to the other modules. The camera calibration module determine the interior orientation parameters of the video camera using the method of planar constraint (Wong and Obaidat, 1993). If the interior orientation parameters of the camera are already known, the measured image coordinates of a stereo pair can be used to compute their corresponding object-space coordinates through the relative and absolute orientation modules.

Figure 1 illustrates the main display menu for performing image coordinate measurement. It provides a display window of 300(H) x 260(V) pixels at 16 gray levels for each of the left and right images. Images consisting of more rows and/or columns than the display windows must be displayed in portions of 300x260 pixels. Most digital images have more than 16 gray levels. DRSTEREO automatically scales the image down to 16 gray levels for the display. A point cursor is provided in each of the two image windows. The two cursors can be moved together or separately. To measure the image coordinates of an image point on the left image, the cursor is manually moved to that point through the PC keyboard. If sub-pixel measurement is desired, a 6x6 window around the point is enlarged to a

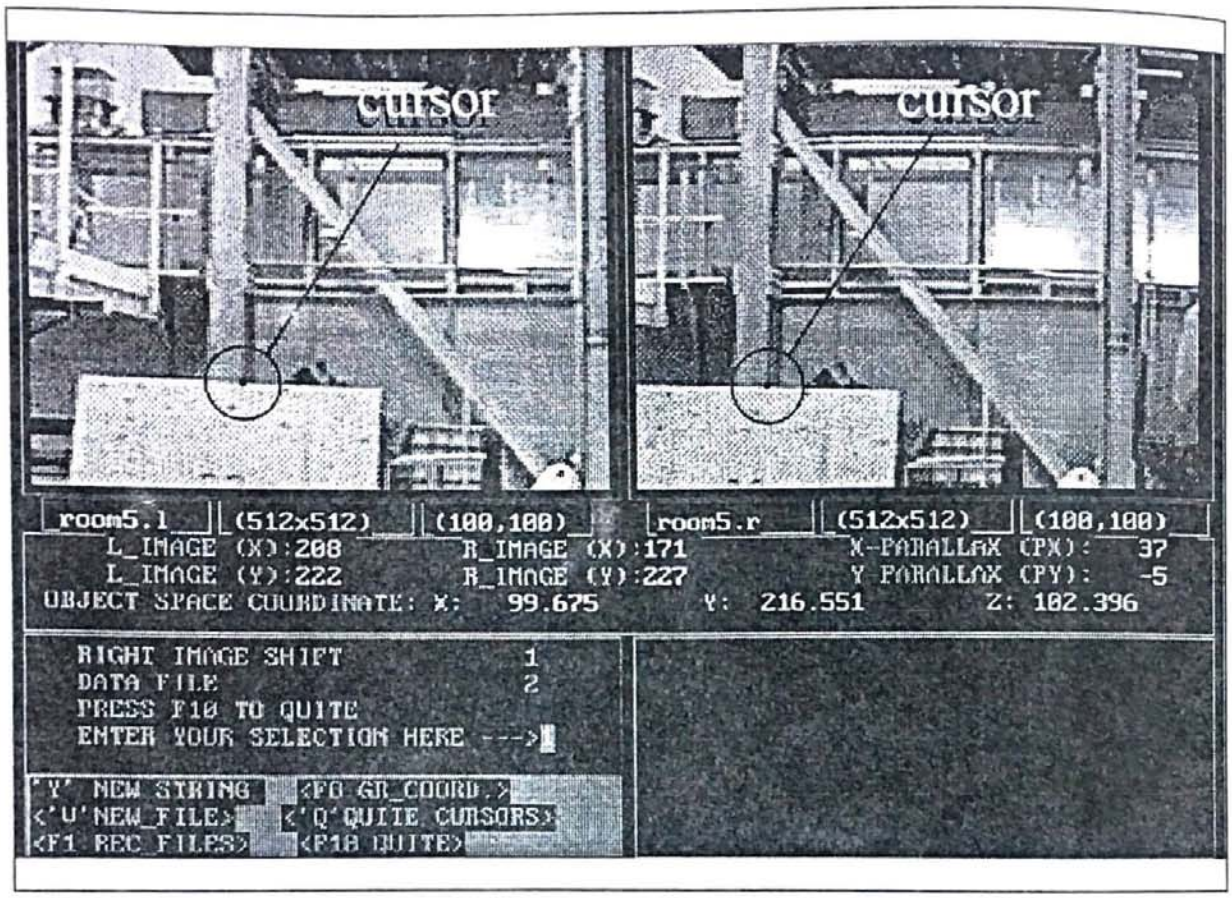

Figure 1. DRSTEREO display menu.

display window of 36 x 36 pixels. The cursor is then transferred to the zoom-window. The resulting least count in image coordinate measurement is therefor equal to 1/6 pixel. The coordinates of the conjugate image point on the right image must be measured in a similar manner. The coordinates of both the left and right cursors are displayed on the menu, and can be recorded to a data file with its identification number and descriptive codes. If the orientation parameters of the two images are already known, the object-space coordinates of the point can also be displayed on the menu. The pair of images can also be viewed stereoscopically by mounting a mirror stereoscope in front of the video monitor. However, it has been found to be more convenient to point to the conjugate image points monoscopically during coordinate measurement.

KNOWLEDGE-BASED ALGORITHMS

A set of knowledge-based algorithms was developed to assist inexperienced users in performing data processing within DRSTEREO and to evaluate the accuracy of the results. It is intended to perform the following specific functions: 1) blunder detection and data snooping; 2) guidance, diagnostics, and counselling in failure modes; 3) accuracy analysis through error propagation; and 4) warning on weak geometric solutions. Solutions for camera calibration, and interior and absolute orientation are performed under the supervision of these knowledge-based algorithms.

Blunder detection, data snooping, and accuracy analysis are effected through standard statistical methods that have been used extensively in analytical photogrammetry. During a weighted least-squares solution, the image coordinates are initially weighted inversely proportional to their estimated standard errors. After the initial iteration, the coordinates are weighted inversely proportional to their residuals. Error propagation was carried through each step of the computation so that estimated standard errors are computed for all computed parameters.

The core of the knowledge base is a set of rules that have been developed to check the integrity of the input data, and to evaluate the computed results. The rules are classified into two types. Type 1 rules are those that, if violated, will result in failure to achieve a successful solution. An error message with suggested remedial actions will be given. Type 2 rules are those that, when violated, will only result in a warning message, and suggested actions. These rules are listed below:

Type 1 rules:

i) The x-coordinate of an image point in the left image should be larger in value than the x-coordinate of the conjugate point in the right image; that is, the left image of the stereo pair should be placed on the left display window during image coordinate measurement.

ii) Both the left and right images must have the same array sizes; e.g. 512x512 pixels.

iii) A minimum of five pairs of conjugate image points are needed for relative orientation.

iv) The image coordinates must follow the convention established by DRSTEREO. The origin (0, 0) can be located at the upper left corner, or at the center of the image; with x representing the columns and increases to the right, and y representing the rows and increases towards the bottom.

v) The object-space coordinates must be right handed with the Z-axis being vertical, and the X-Y plane being horizontal.

vi) Computed standard error of unit weight should not be larger than 2 times the a priori standard error of unit weight.

vii) A solution for absolute orientation requires at least 2 known horizontal control and three vertical control points.

viii) For camera calibration using planar constraint, the approximate object-space coordinates of four points on the plane and the length of one line must be provided.

ix) For camera calibration using planar constraint, each quarter of the stereo model should have at least four measured image points. The should be at least 35 measured image points in the stereo model.

Type 2 rules:

i) Each of six regions within the stereo overlap area of each image should have at least one image point for the purpose of relative orientation. Furthermore, no region should have more than 3 times the number of image points in any of the other regions.

i) Separation between the two camera positions should be arger than 0.5 m.

i) The two images of a stereo pair should overlap more than 0%.

) An image point is rejected from a solution if either its x- or residual exceeds 3 times the computed standard error of unit ight.

If an iterative least-square solution fails to converge after a cified maximum number of iterations, the convergence shold is increased by 20%. This process is repeated until convergence threshold reaches a specified value, such as 0.1 pixel. If the solution still fails to converge, results from the last iteration is provided as output with an error message.

vi) Convergence threshold should have a value between 0.001 and 0.1 of the a priori standard error of unit weight.

vii) Computed standard error of unit weight should starts to decrease no later than the 5th iteration.

viii) Good data usually result in convergence by the 20th iteration.

ix) In relative orientation, the computed estimated standard errors should not exceed ±2 degrees for rotation angles, and ± 3 cm for positions of exposure centers.

x) For absolute orientation, each quarter of the stereo model area should have at least one control point, and no quarter should have more than 3 times the number of control points in any of the other three quarters.

xi) For absolute orientation, the control points should not all lie on a plane.

x) Object-space coordinates of a control points is rejected from a solution if the residual of any of the three coordinates (X, Y, Z) exceeds 3 times its estimated standard error.

xi) In absolute orientation, the estimated standard errors for the computed parameters should not exceed the following:

Rotation angles:	± 0.5 degree
Translation parameters:	± 3 cm
Scale factor:	± 0.001

TEST RESULTS

DRSTEREO has been tested using stereo images acquired with a SONY CCD-F55 video camcorder, which has a focal plane consisted of 250,000 effective pixels and a 8.5-68 mm zoom lenses. The images were digitized with an EPIC frame grabber installed in a 486-PC. The camera was calibrated using a brick wall. The stereo images included scenes of brick buildings, a concrete walkway, and an outdoor sculpture.

Relative orientation of the stereo pairs resulted in standard deviations ranging from ±0.07 to ± 0.25 pixels in the image residuals, verifying the capability of the camera calibration algorithm to determine the interior geometry of the camcorder. After absolute orientation, object-space coordinates were found to be accurate only to the equivalent of ± 2 pixels (1 σ) in the image plane. The degradation in accuracy was most likely due to difficulties in identifying the exact locations of the check points in the images. The object-space coordinates of the check points were obtained by conventional ground surveys. The test results showed that resolution is likely to be the major limiting factor in using video camcorders for outdoor measurements.

CONCLUSIONS

DRSTEREO was developed to perform geometric measurements using stereo video images in support of video documentation of engineering construction. It is intended to be used by engineers to extract quantitative measurements, such as dimensions, areas and volummes, from video images. Due to limitation in resolution, video cameras can never replace conventional cameras in photogrammetric measurements. Nevertheless, as video camcorder continue to gain popularity as a video recording device, DRSTEREO provides a convenient means to extract useful measurements from such images.

DRSTEREO is not dependent on the devices needed to generate the digital images. Both the calibration algorithm and the knowledge base rules are equally applicable to digital images generated from conventional photographs. Continuing research is being directed towards the refinement and extension of the knowledge-base algorithms and further automation of the image coordinate measurement process.

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